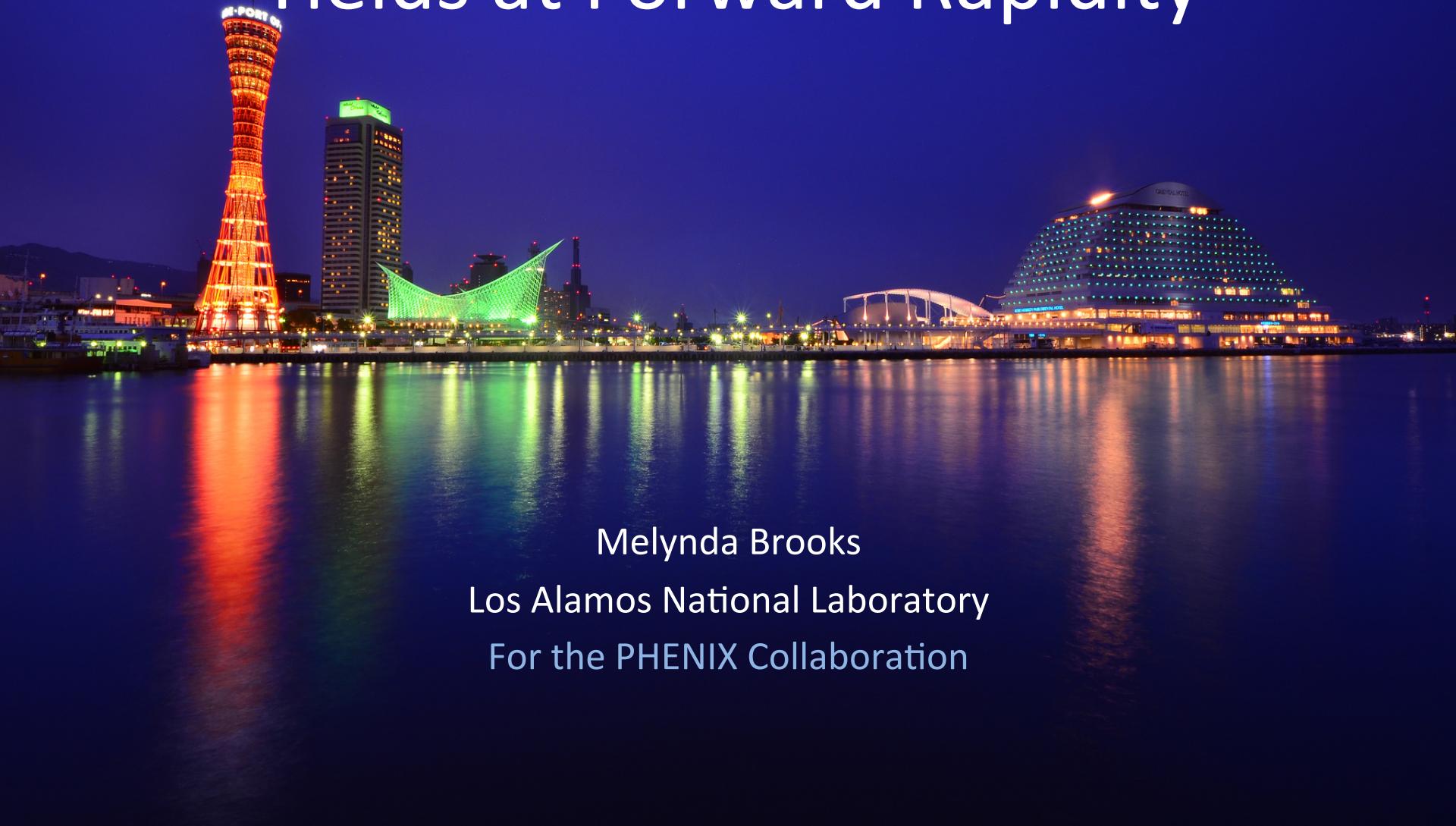


PHENIX Results on Heavy-Flavor Yields at Forward Rapidity

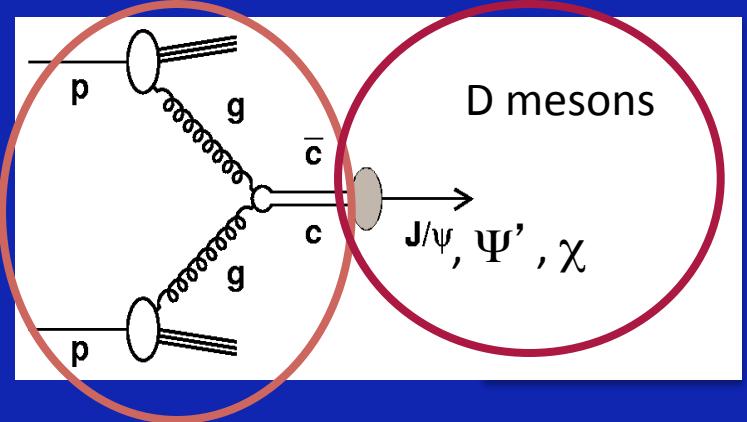


Melynda Brooks
Los Alamos National Laboratory
For the PHENIX Collaboration

Open and Closed Heavy Flavor Production

Factorize Production:

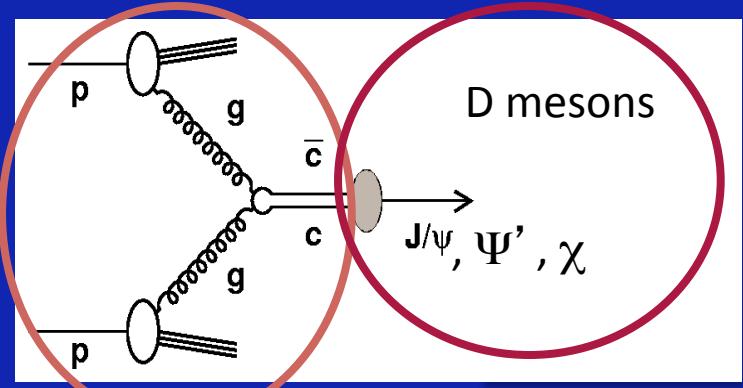
- pQCD to calculate cc production
- cc propagation and hadronization



Open and Closed Heavy Flavor Production

Factorize Production:

- pQCD to calculate cc production
- cc propagation and hadronization



Initial-State modifications beyond p-p extrapolation:

- Parton Distribution Functions modified in nucleus
- Energy loss of partons traversing nucleus
- Cronin modification of p_T spectra

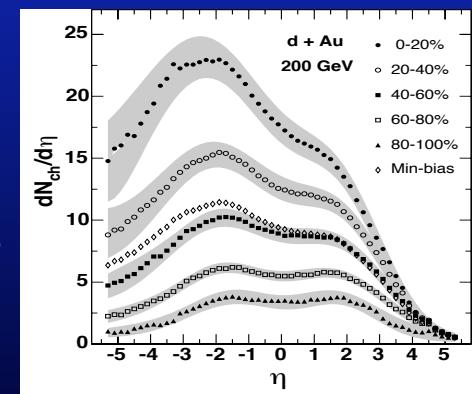
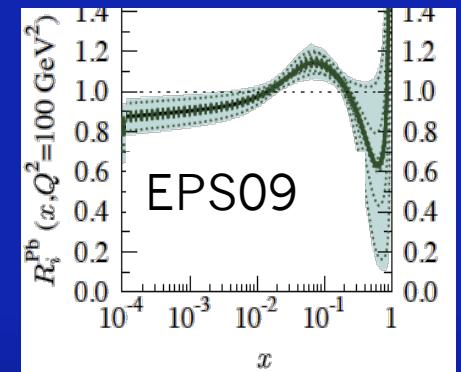
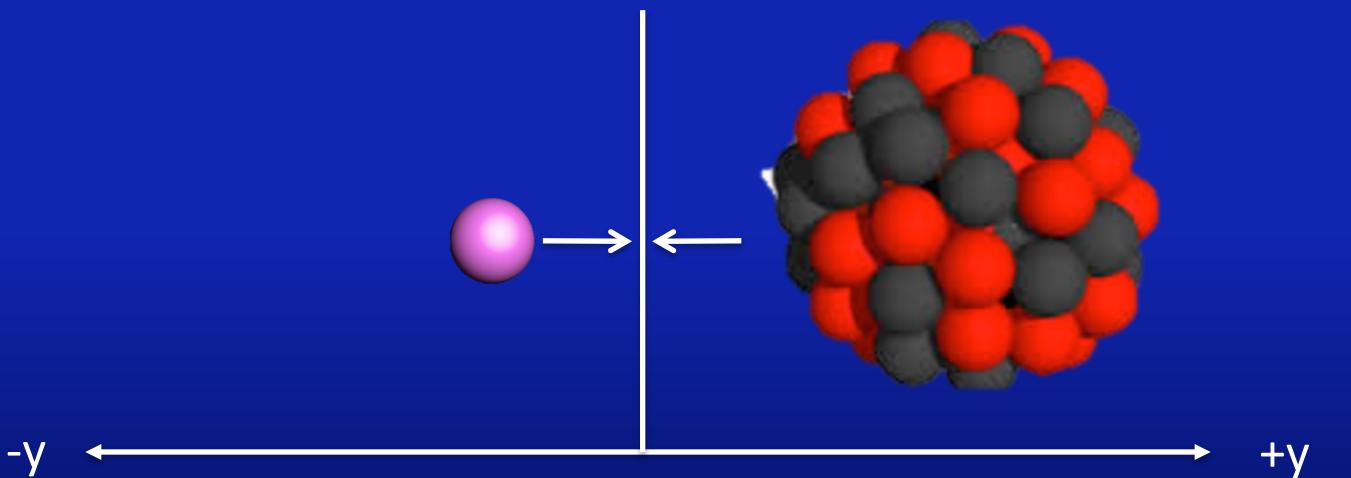
Propagation and hadronization can include suppression from:

- Breakup of charmonia in cold nucleus
- Suppression of charmonia due to interactions with co-movers

QGP-Specific effects: radiative energy loss, Debye screening

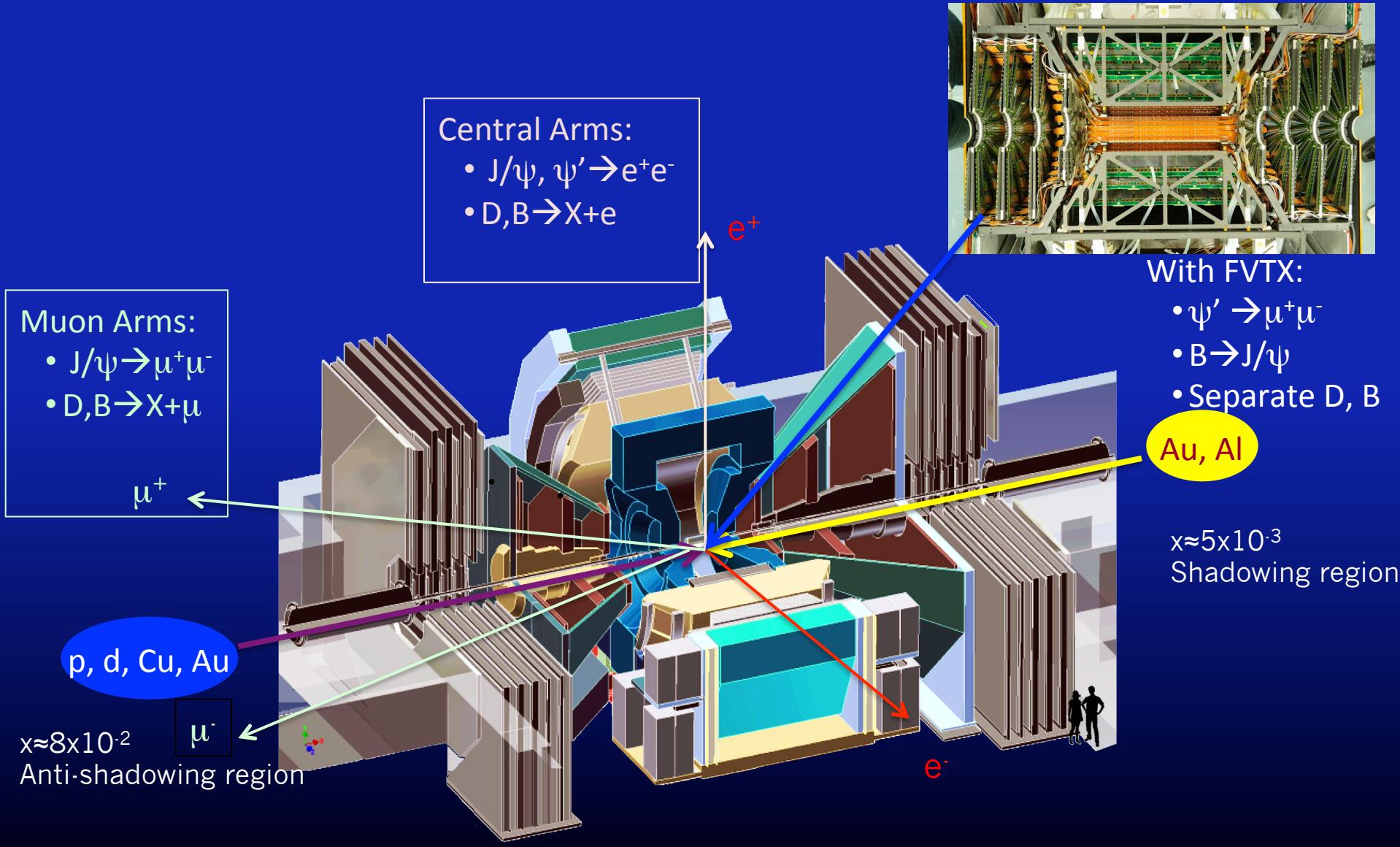
Rapidity Dependencies

- Exploit rapidity dependencies to help separate hot and cold nuclear matter effects



QGP effects slightly stronger at mid-rapidity in symmetric A+A
CNM effects stronger at forward/backward rapidity in symmetric A+A

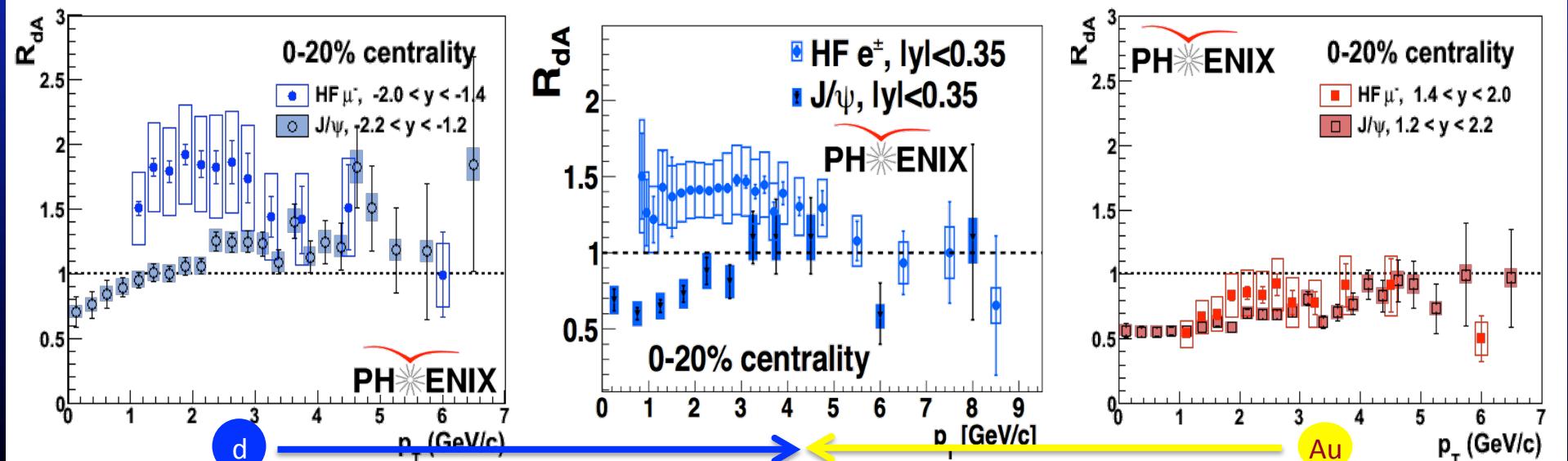
The PHENIX Detector



Results: p+p, p+A and d+Au

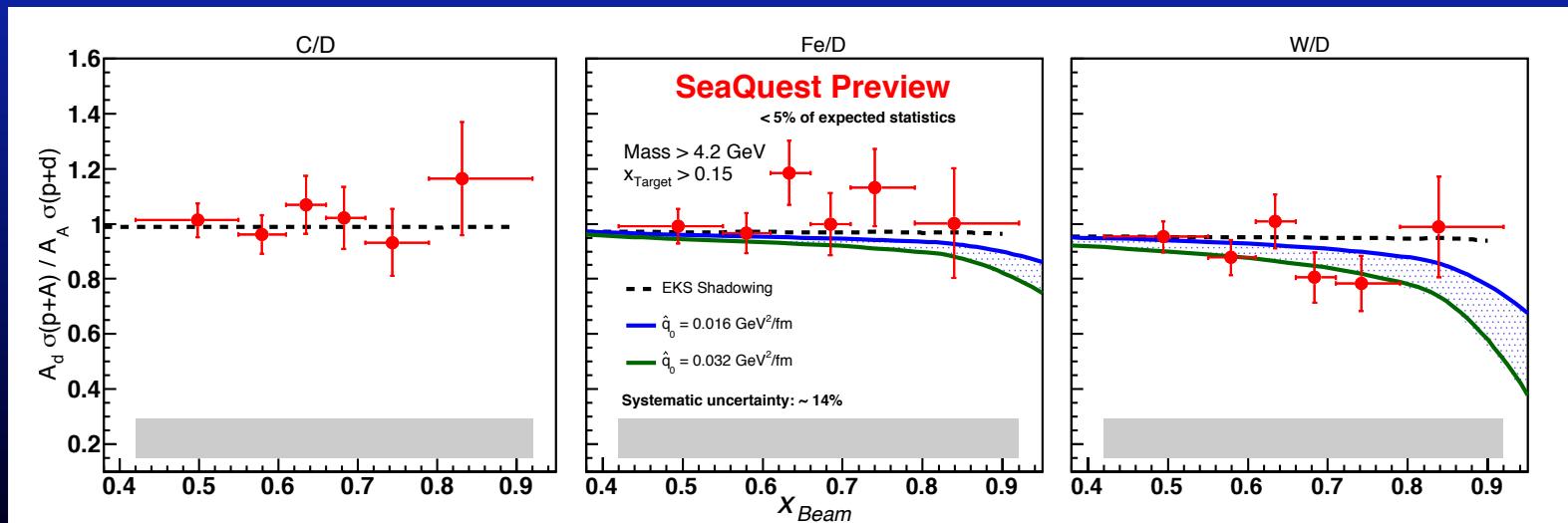
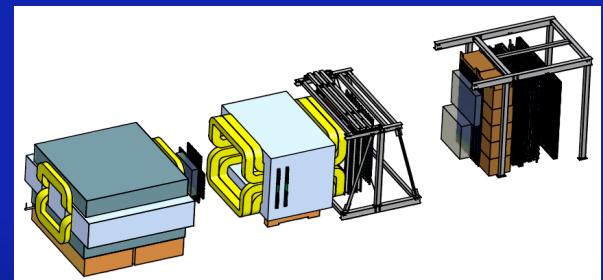
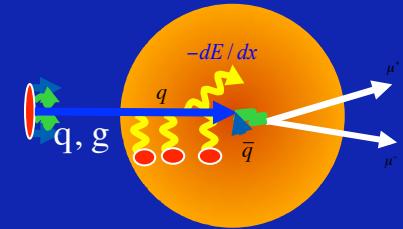
Results: p+p and d+Au

- Open heavy flavor $R_{d\text{Au}}$ shows a different rapidity dependence from J/ψ
- Similar suppression at forward rapidity – initial state effects (shadowing, e-loss)
- Enhancement at backward – incoherent multiple scattering* gives Cronin-type behavior
- Divergence at mid/backward rapidity – breakup in CNM, comovers
- Can we quantify different cold nuclear matter effects better?



Initial State Partonic E-Loss

- FNAL E906 - unique access to unambiguous CNM partonic energy loss – kinematic region where shadowing would be minimal, no final-state effects with DY
- First data collected with initial results produced
- We can use these measurements to constrain CNM at RHIC

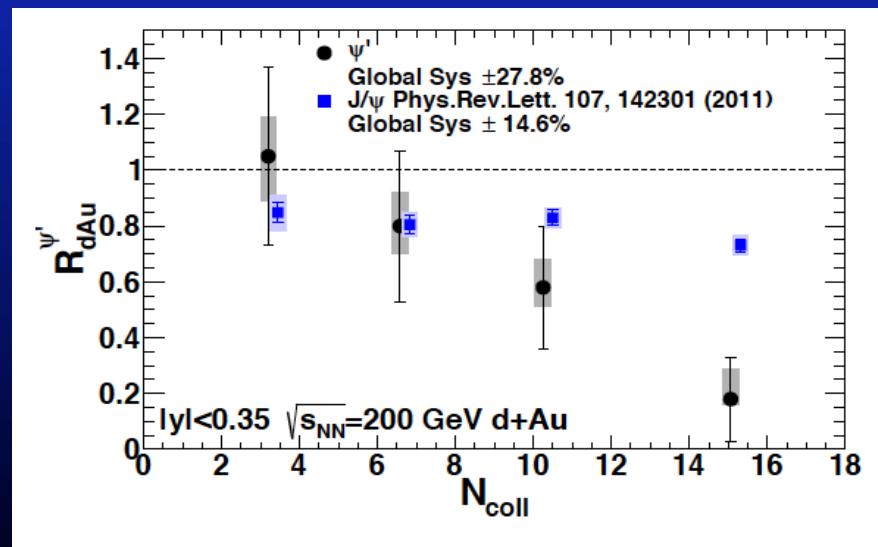


First preliminary results from subset of data

ψ' :J/ ψ , Central Rapidity, d+Au

(more details in Tony Frawley's talk)

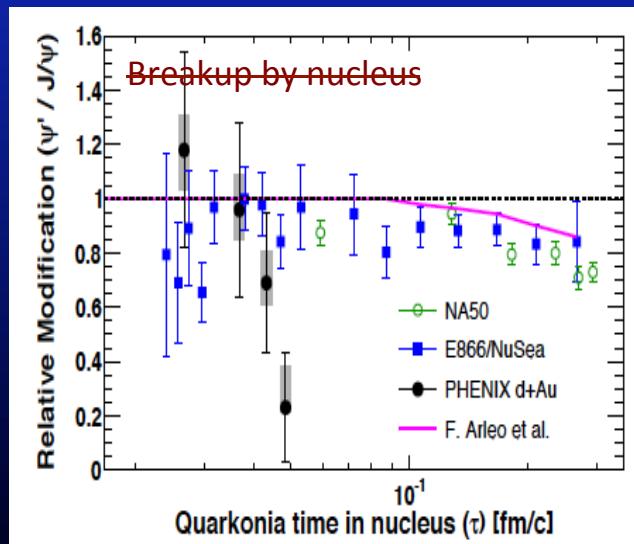
- PHENIX ψ' suppressed more than J/ ψ at central rapidity, in d+Au. Time spent in nucleus (breakup) does not by itself explain PHENIX data.



ψ' :J/ ψ , Central Rapidity, d+Au

(more details in Tony Frawley's talk)

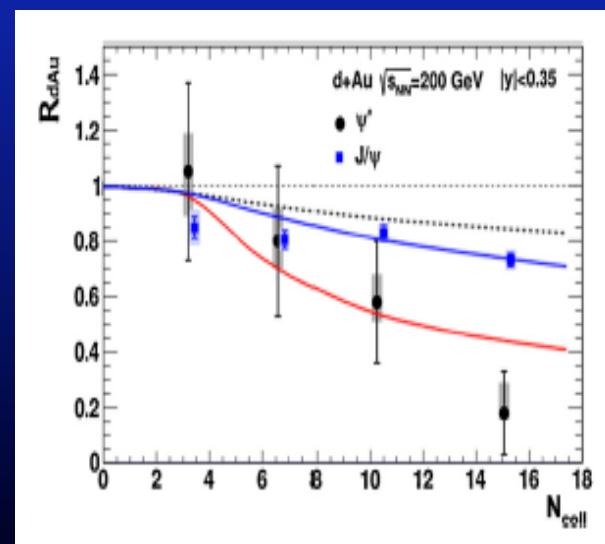
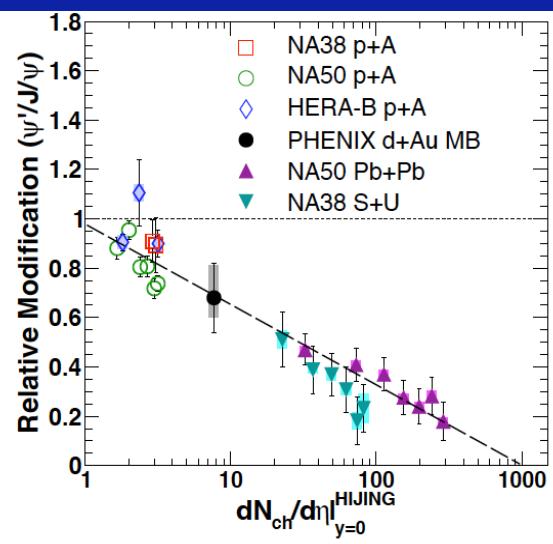
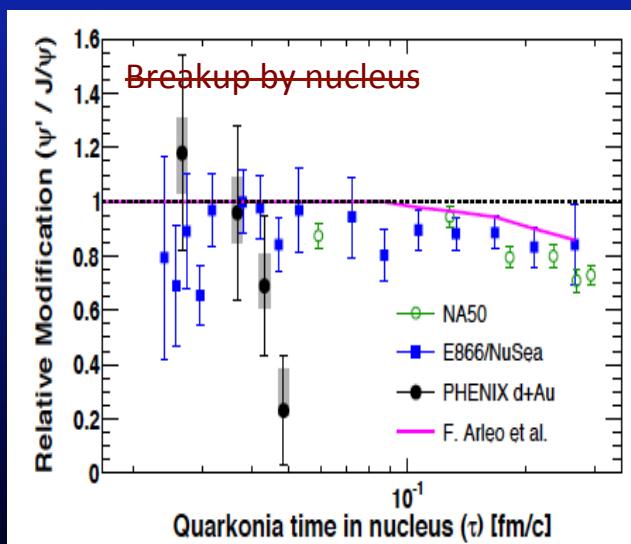
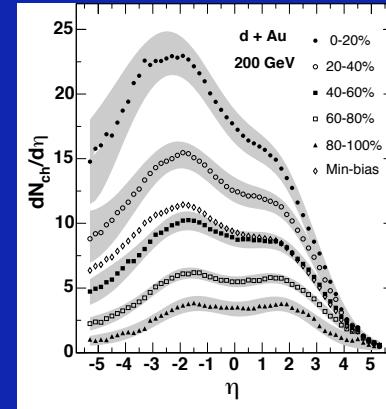
- PHENIX ψ' suppressed more than J/ ψ at central rapidity, in d+Au. Time spent in nucleus (breakup) does not by itself explain PHENIX data.
- Interactions with co-movers reproduces suppression pattern at this rapidity
- Can we fill out the $dN/d\eta$ dependence more and see if co-mover model holds?



ψ' :J/ ψ , Central Rapidity, d+Au

(more details in Tony Frawley's talk)

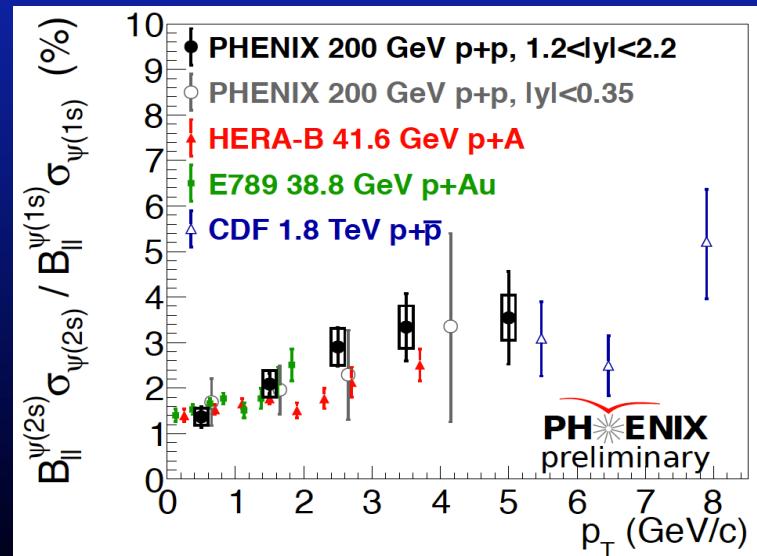
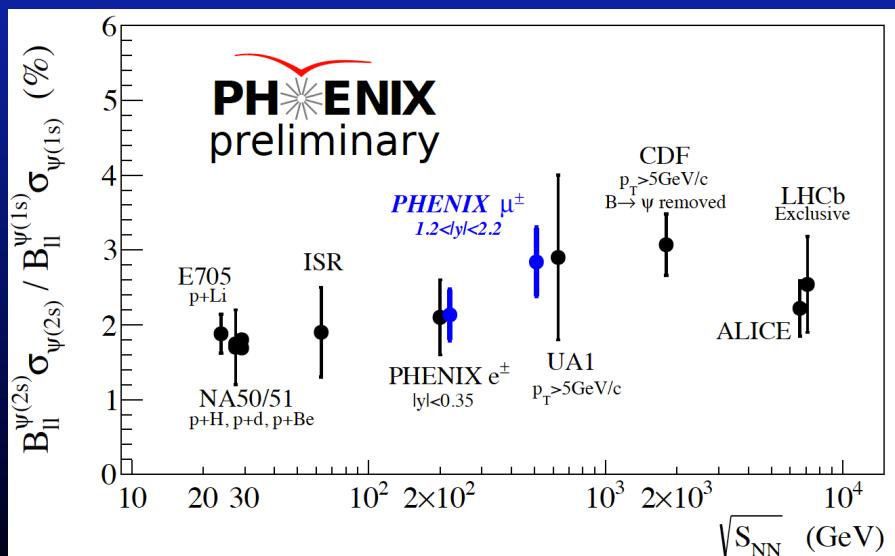
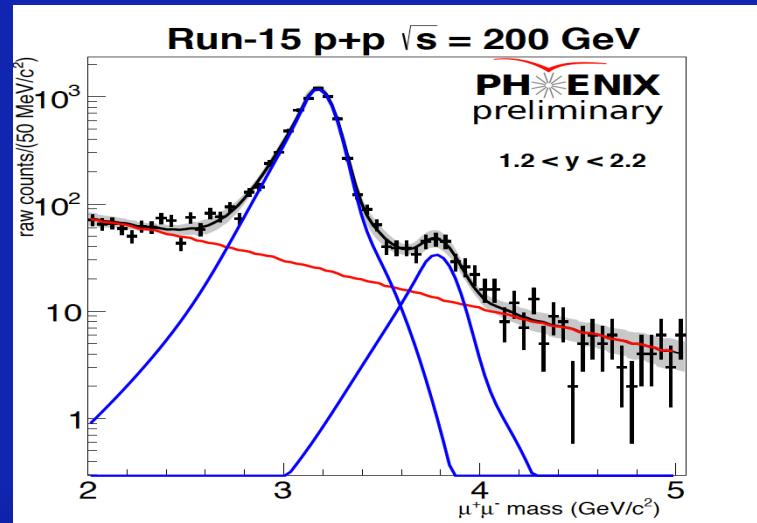
- PHENIX ψ' suppressed more than J/ ψ at central rapidity, in d+Au. Time spent in nucleus (breakup) does not by itself explain PHENIX data.
- Interactions with co-movers reproduces suppression pattern at this rapidity
- Can we fill out the $dN/d\eta$ dependence more and see if co-mover model holds?



Forward Rapidity ψ' :J/ ψ in p+p

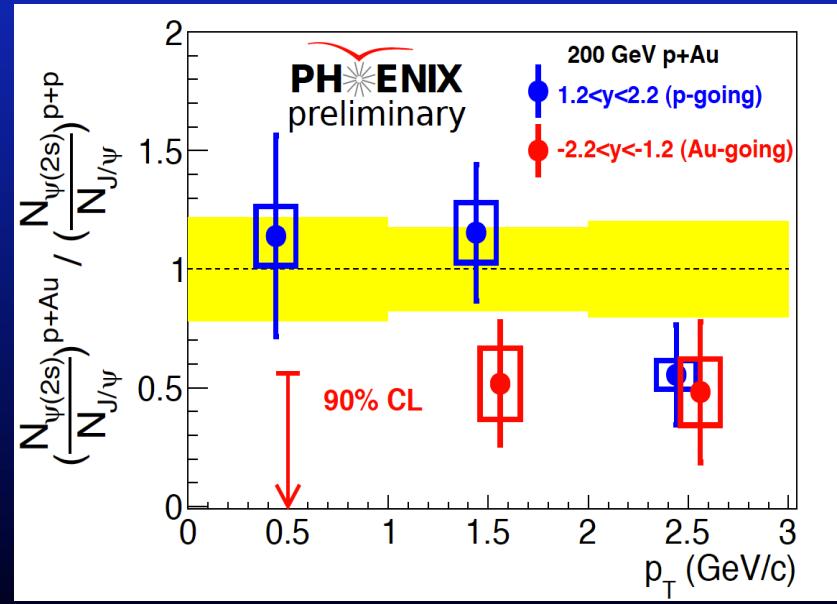
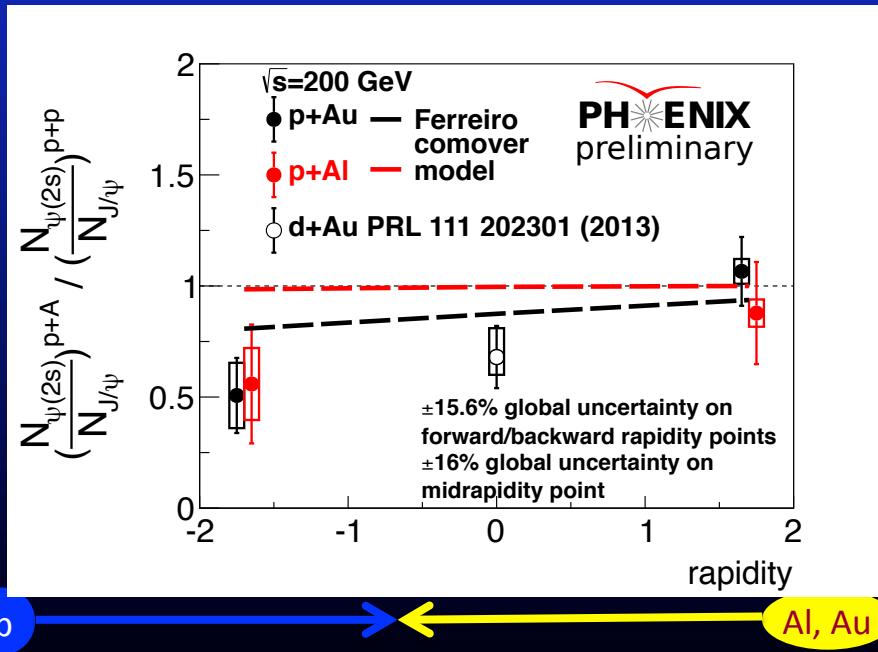
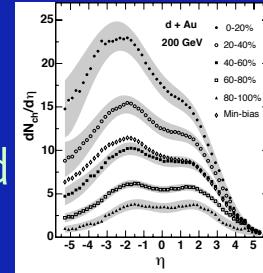
(new results)

- Run 13 510 GeV, Run 15 200 GeV
- FVTX Detector allows clean separation of J/ ψ , ψ' peaks, rejects hadronic backgrounds
- Extract total ψ' :J/ ψ and p_T -dependence (200 GeV)



Forward Rapidity ψ' :J/ ψ in p+Al, p+Au (new results)

- Run 15 p+Al and p+Au 200 GeV runs analyzed at forward and backward rapidity
- Suppression in the A-going direction but not p-going \rightarrow interaction with co-movers?
- A-going formation time allows some nuclear medium interaction, but should be relatively small
- In progress: FVTX can also provide ψ' :J/ ψ versus event multiplicity

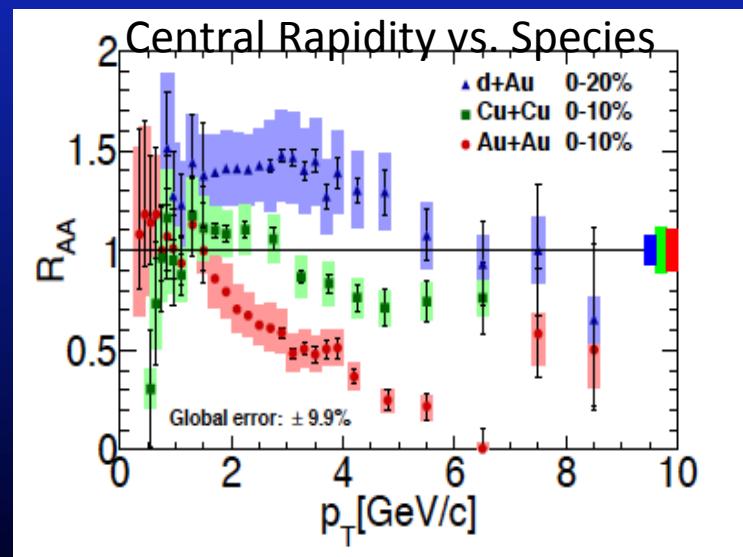


d+A, p+A Conclusions

- Suppression of both open and closed heavy flavor at similar levels at forward rapidity indicates initial state CNM effects
- Backward rapidity shows enhancement of open heavy flavor which can be reproduced by incoherent multiple scattering effects
- Increased suppression of J/ψ w.r.t. open heavy flavor at backward rapidity indicates some breakup of J/ψ , consistent with co-mover effects
- p-A suppression of ψ' w.r.t. J/ψ , rapidity-dependence could also be explained by co-mover effects

New Forward Rapidity Open Charm/ Beauty Measurements in Progress

Understanding Large Suppression in A+A, c/b components



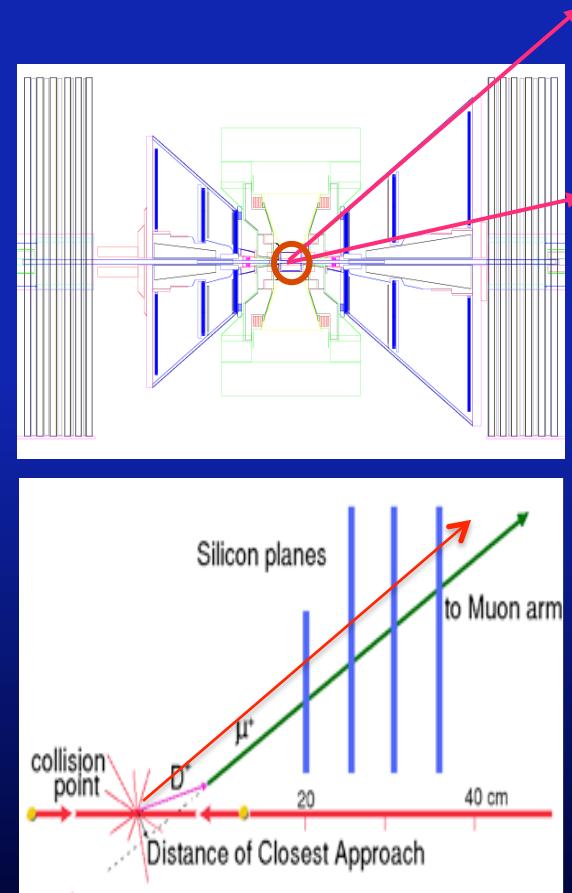
Heavy Flavor Measurements With FVTX

Two Methods for Measuring D/B:

- Direct measurement of $B \rightarrow J/\psi$
- Separation of D/B components in single muon spectra

Heavy Flavor Extraction Method:

- Precision vertex determined with combination of FVTX+VTX detectors
- Muon system tracks projected to FVTX, select best candidate track within a search window
- Perform combined fit of MuTr + FVTX hits and project to vertex
- Dca_r distributions different for prompt, short- and long-lived decays



Work in Progress: $B \rightarrow J/\psi$ (forward rapidity)

Method :

- select good J/ψ s, matched to the FVTX detector, and plot muon dca
- Model prompt J/ψ , $B \rightarrow J/\psi$, and any background dcas (combinatorial, mismatched)
- Deconvolute the multi-component dca distribution contributions
- Correct for J/ψ , $B \rightarrow J/\psi$ acceptance*efficiencies

Status

- Modeled dcas, Good matching between MC and real data
- $P+p$ extracted and fit
- $Cu+Au$ extracted and fit
- Systematic Error checks underway
- Expect results soon

Open HF analysis with single μ
also underway
(very similar methods)

Work in Progress: $B \rightarrow J/\psi$ (forward rapidity)

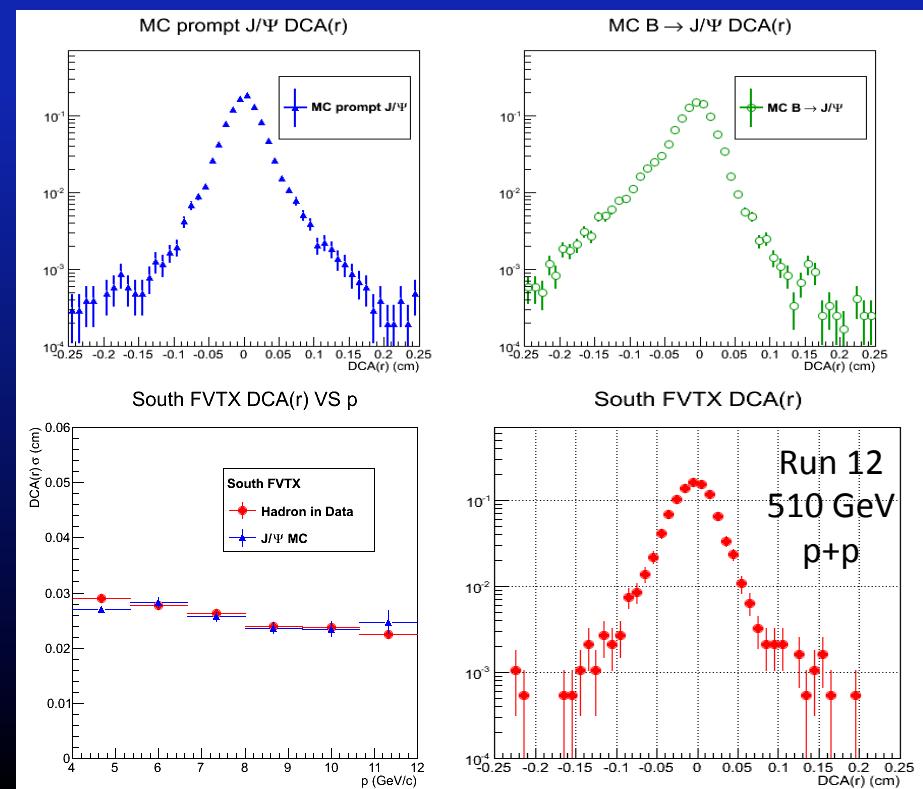
Method :

- select good J/ψ s, matched to the FVTX detector, and plot muon dca
- Model prompt J/ψ , $B \rightarrow J/\psi$, and any background dcas (combinatorial, mismatched)
- Deconvolute the multi-component dca distribution contributions
- Correct for J/ψ , $B \rightarrow J/\psi$ acceptance*efficiencies

Status

- Modeled dcas, Good matching between MC and real data
- $P+p$ extracted and fit
- Cu+Au extracted and fit
- Systematic Error checks underway
- Expect results soon

Open HF analysis with single μ
also underway
(very similar methods)



Work in Progress: $B \rightarrow J/\psi$

(forward rapidity)

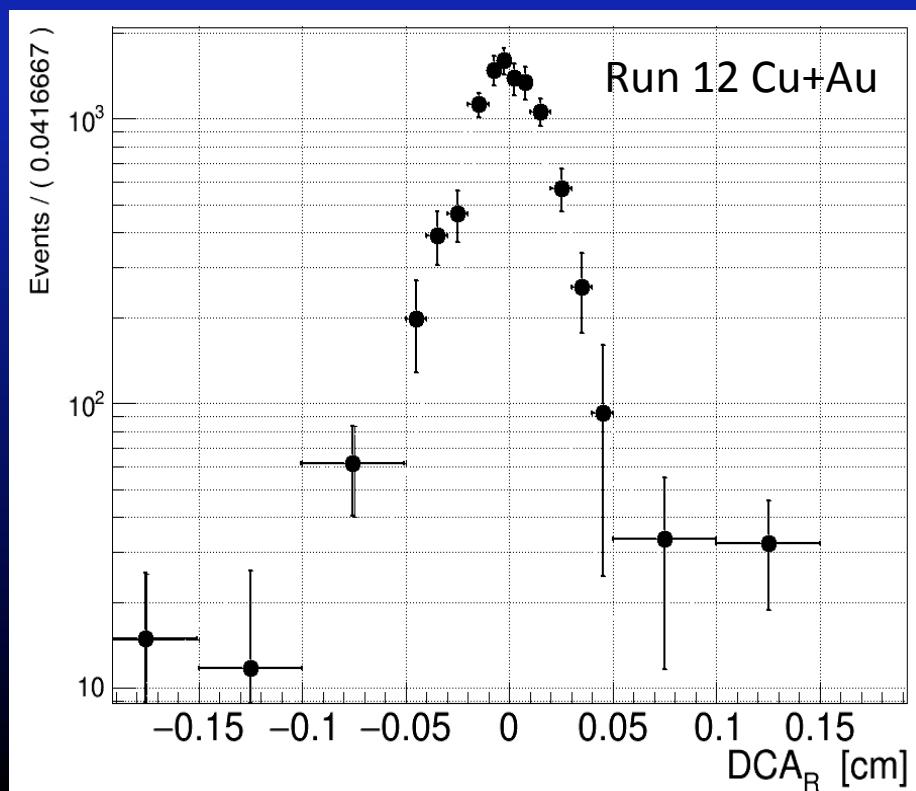
Method :

- select good J/ψ s, matched to the FVTX detector, and plot muon dca
- Model prompt J/ψ , $B \rightarrow J/\psi$, and any background dcas (combinatorial, mismatched)
- Deconvolute the multi-component dca distribution contributions
- Correct for J/ψ , $B \rightarrow J/\psi$ acceptance*efficiencies

Status

- Modeled dcas, Good matching between MC and real data
- $P+p$ extracted and fit
- Cu+Au extracted and fit
- Systematic Error checks underway
- Expect results soon

Open HF analysis with single μ
also underway
(very similar methods)



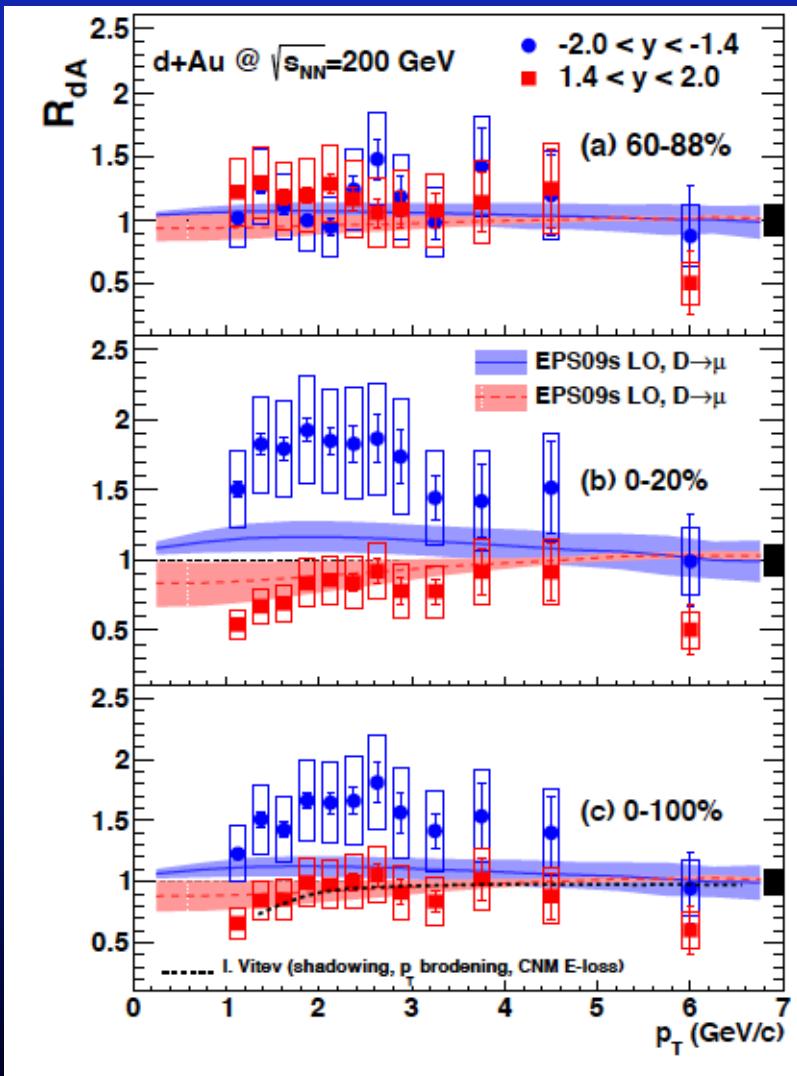
Additional Conclusions

- Coming soon: Forward/backward $B \rightarrow J/\psi$ and separation of D/ $B \rightarrow \mu + X$ for p+p, p+A, Cu+Au, Au+Au

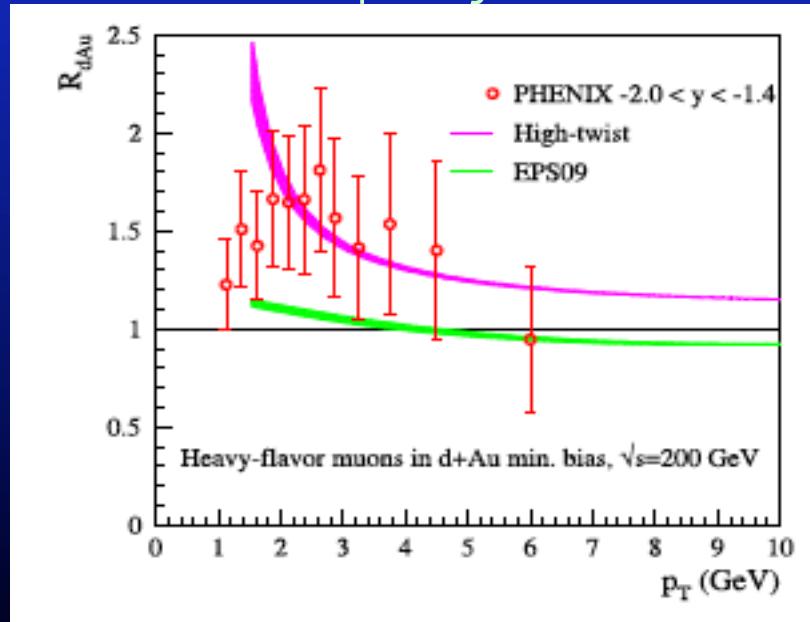
Thank you

BACKUPS

Results: p+p and d+Au



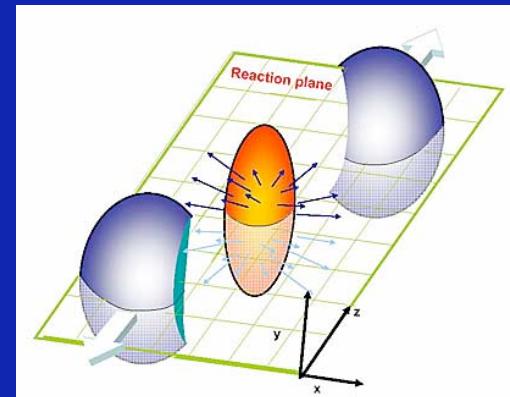
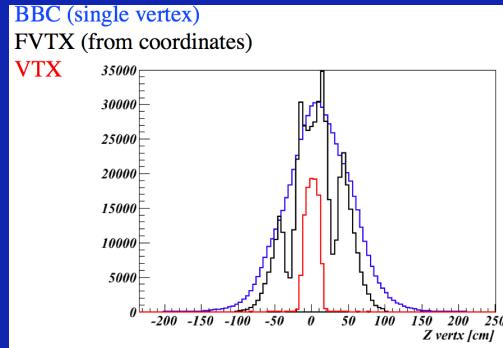
- Forward rapidity results consistent with models which include shadowing, Cronin and initial-state e-loss
- Model with incoherent multiple scattering better describes backward rapidity data



Enhancements With FVTX

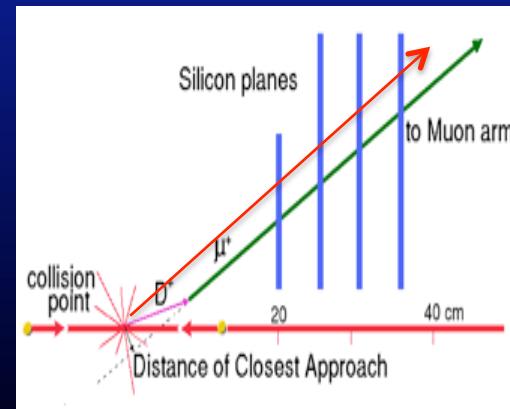
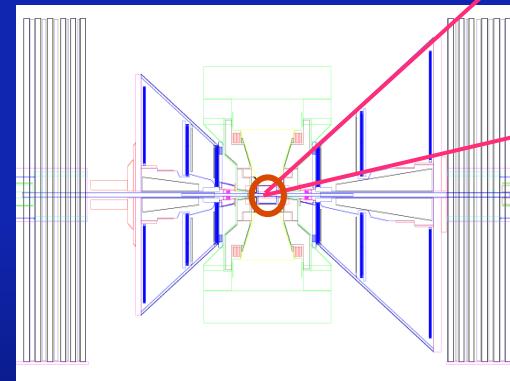
General:

- Contribute to measurement of event vertex(es)
- Provide reaction plane measurement
- Provide relative luminosity measurement in p-p
- Provide multiplicity trigger



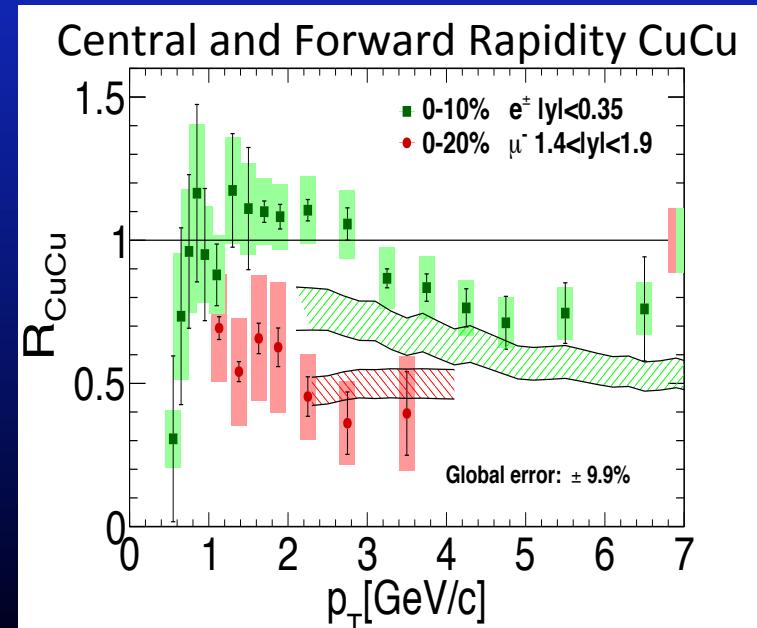
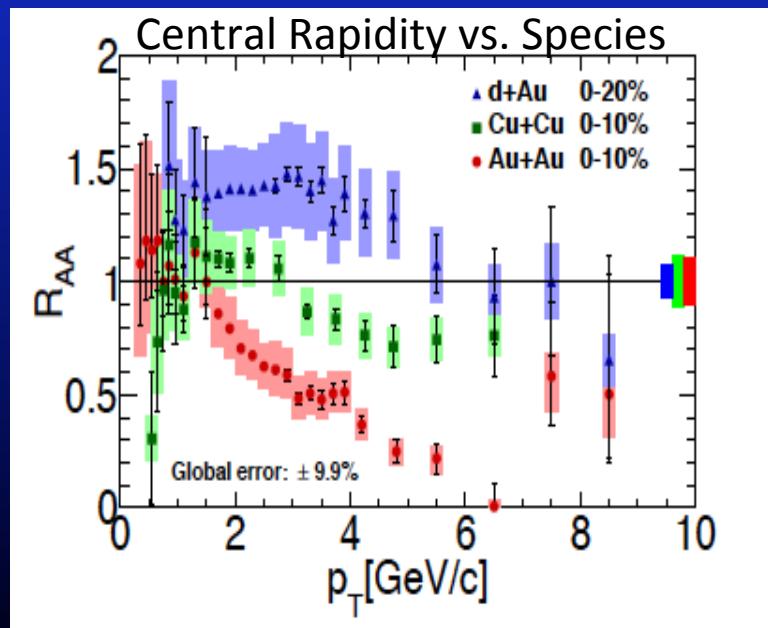
Enhance Forward Muon Arm Analyses

- Opening angle measurement before absorber improves dimuon mass resolution
- Combined FVTX-MuTr track fit, DCA cuts provide rejection of some hadronic backgrounds
- Isolation Cuts to enhance signal:background
- DCA measurement to separate prompt particles from non-prompt decay particles



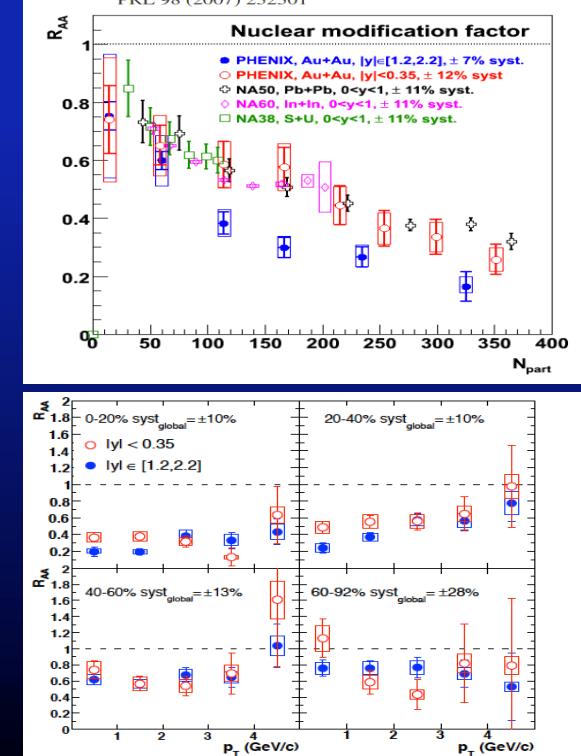
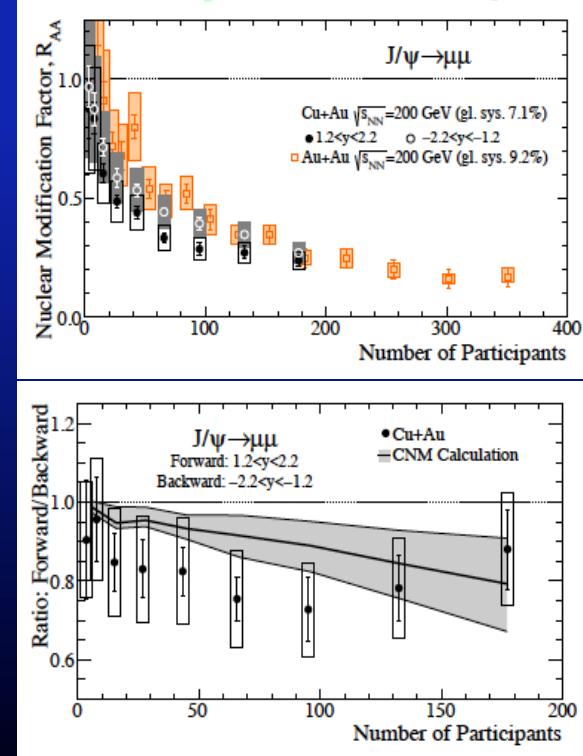
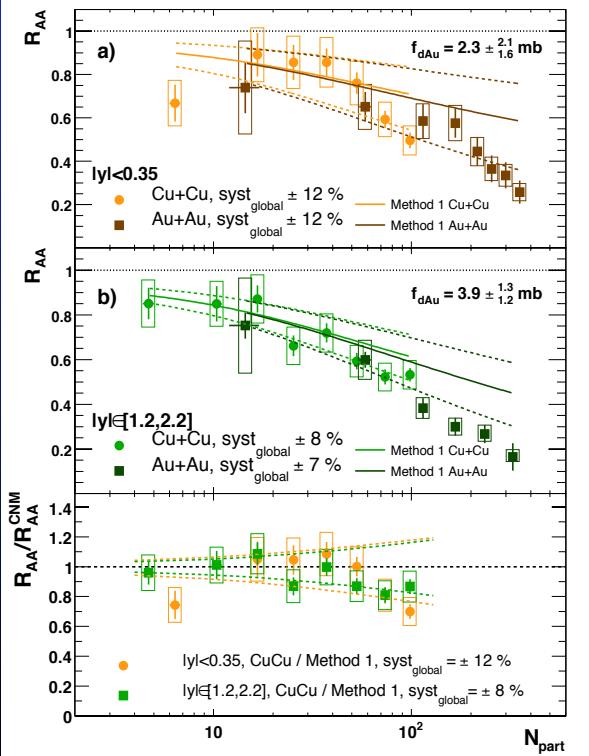
Open Heavy Flavor in A+A

- Open heavy flavor also shows significantly more suppression at forward rapidity than central rapidity in CuCu collisions → large CNM effects?
- In AuAu collisions, central rapidity starts to be highly suppressed
- What will forward rapidity show?
- What will we learn by separation of c, b?



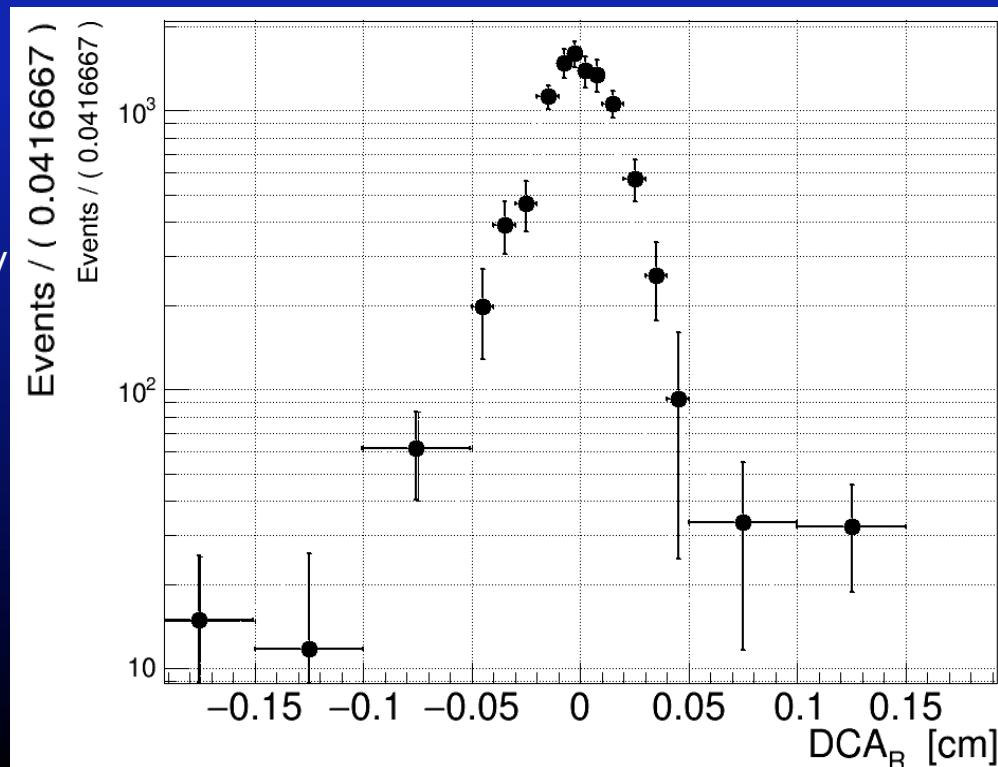
J/ ψ in A+A

- J/ ψ in CuCu consistent with CNM extrapolations
- J/ ψ in CuAu rapidity dependence more consistent with CNM effects than QGP effects
- J/ ψ in AuAu has larger suppression at forward rapidity than central rapidity, perhaps indicating strong CNM effects again
- How well can we separate any residual QGP effects from CNM?



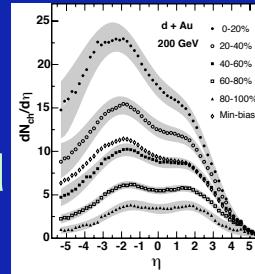
Work in Progress: $B \rightarrow J/\psi$ (forward rapidity)

- Method :
 - select good J/ψ 's, matched to the FVTX detector, and plot muon dca
 - Model prompt J/ψ , $B \rightarrow J/\psi$, and any background (combinatorial, mismatched)
 - Deconvolute the multi-component dca distribution contributions
 - Correct for J/ψ , $B \rightarrow J/\psi$ acceptance*efficiencies
- Status
 - Good matching between MC and real data distributions
 - Systematic Error checks underway
 - p+p and Cu+Au
- Open HF analysis with single μ also underway
(very similar methods)



Forward Rapidity ψ' :J/ ψ in p+Al, p+Au (new results)

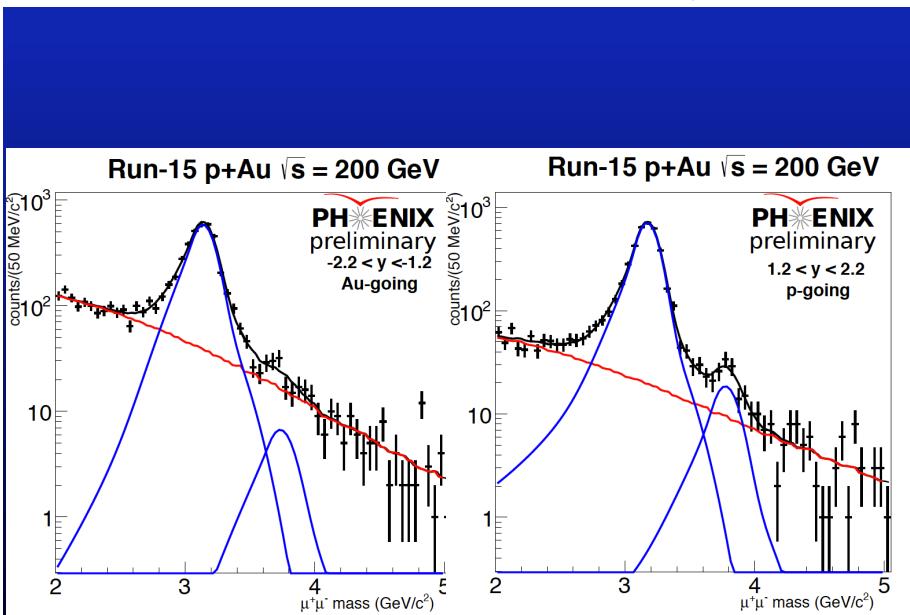
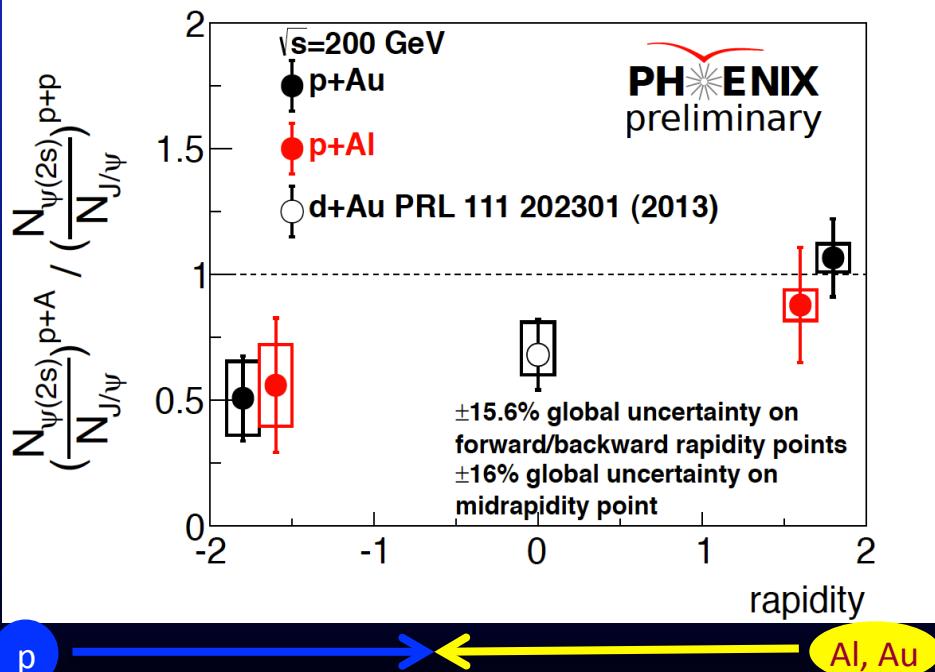
- Run 15 p+Al and p+Au 200 GeV runs analyzed at forward and backward rapidity
- Suppression in the A-going direction but not p-going \rightarrow interaction with co-movers? Other?
- p_T dependence statistically
- FVTX can provide event mul



The formation time for the different rapidities reached at RHIC are given in Table 1. As it

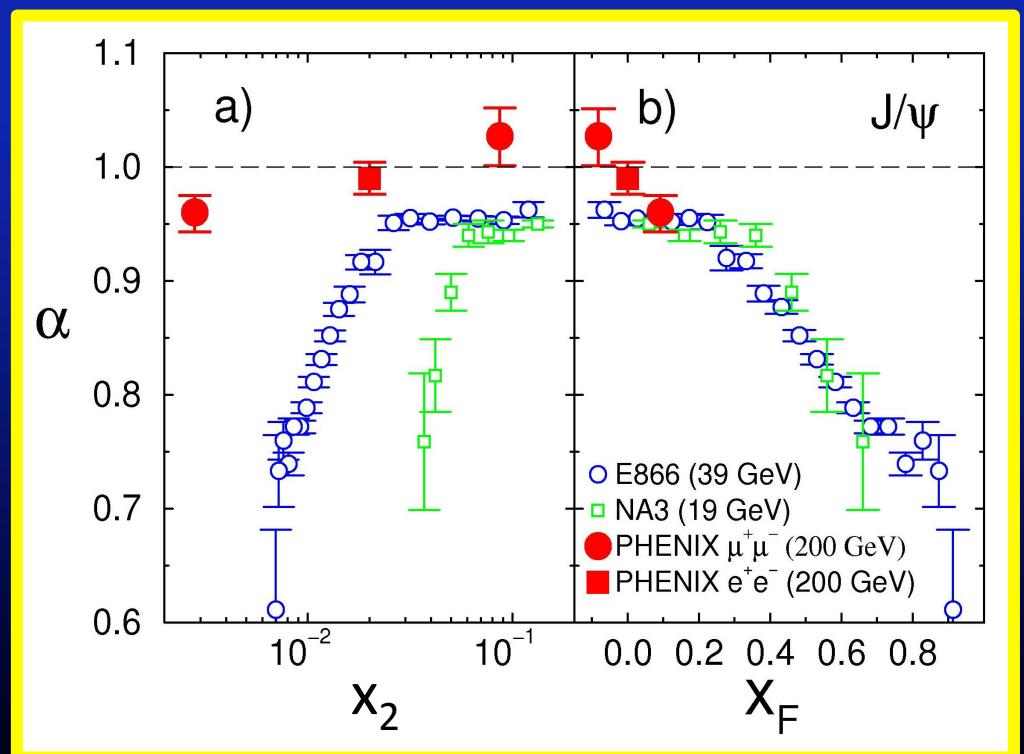
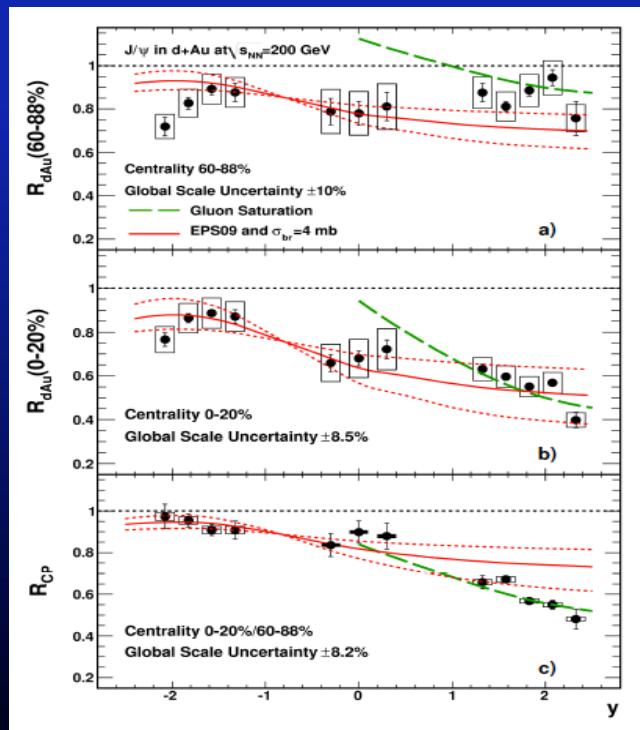
y	$\gamma(y)$	$t_f(y)$	y	$\gamma(y)$	$t_f(y)$
-2.0	14.4	5.1 fm	0.0	106	36.7 fm
-1.5	23.7	8.3 fm	+1.5	476	166 fm
-1.0	39	14 fm	+2.0	786	271 fm

Table 1. Boost and formation-time y -dependence in the Au rest frame of the ψ at $\sqrt{s_{NN}} = 200$ GeV.



Results: x_2 Dependence

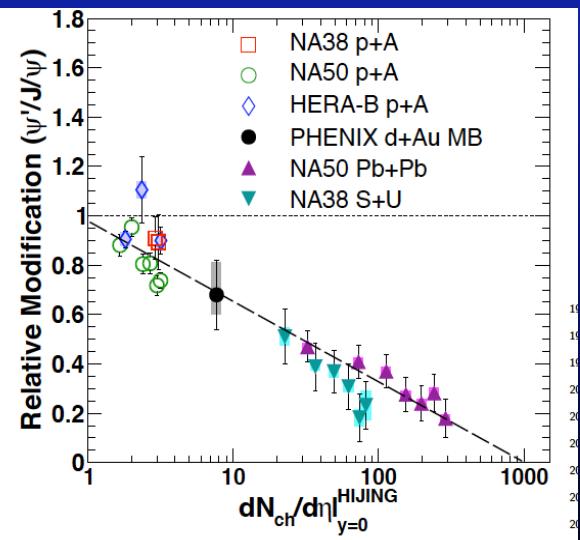
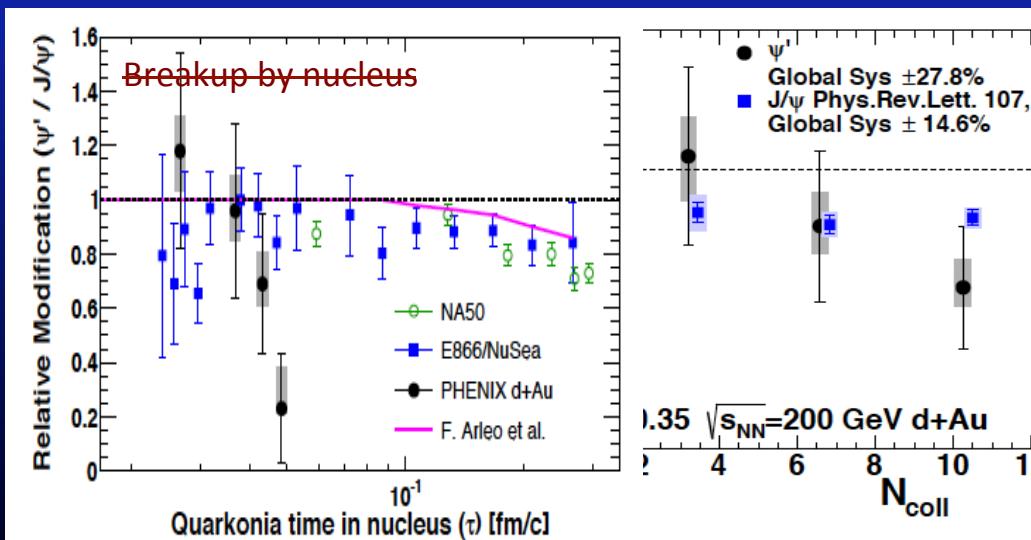
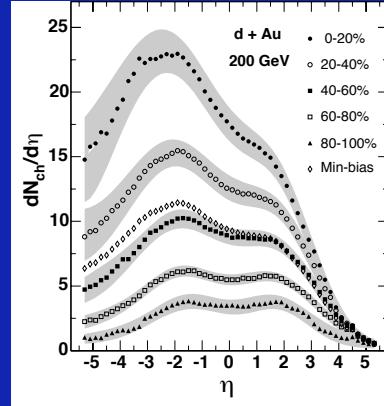
- We do not see x_2 scaling, which would be indicative of gluon shadowing
- Initial-state energy loss (x_1 -dependent) and final-state effects?
- Difficult to separate initial state effects at RHIC



ψ' :J/ ψ , Central Rapidity, d+Au

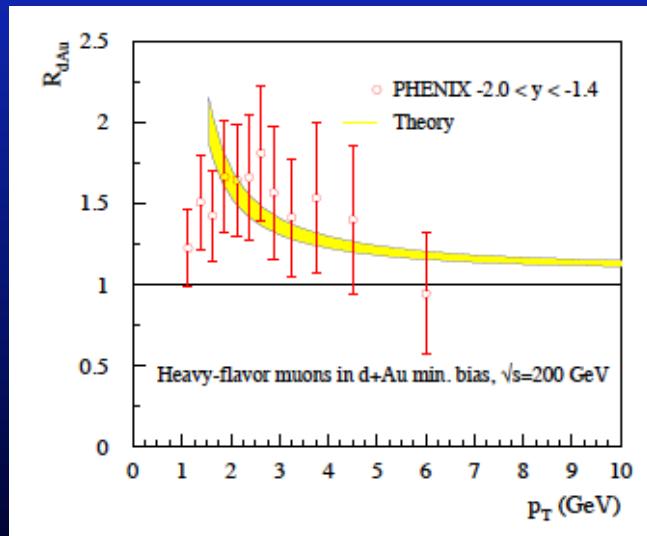
(more details in Tony Frawley's talk)

- PHENIX ψ' suppressed more than J/ ψ at central rapidity, in d+Au. Time spent in nucleus (breakup) does not by itself explain PHENIX data.
- Universal trend with $dN_{ch}/d\eta$ for several systems, up to 200 GeV
- Is this effect of co-movers? Other?
- Can we fill out the $dN/d\eta$ dependence more?



Results: p+p and d+Au

- Open heavy flavor $R_{d\text{Au}}$ shows a different rapidity dependence from J/ψ
- Similar suppression at forward rapidity – initial state? (shadowing, e-loss, etc.)
- Divergence at central/forward rapidity – final state?



d



Au